Chapter 6

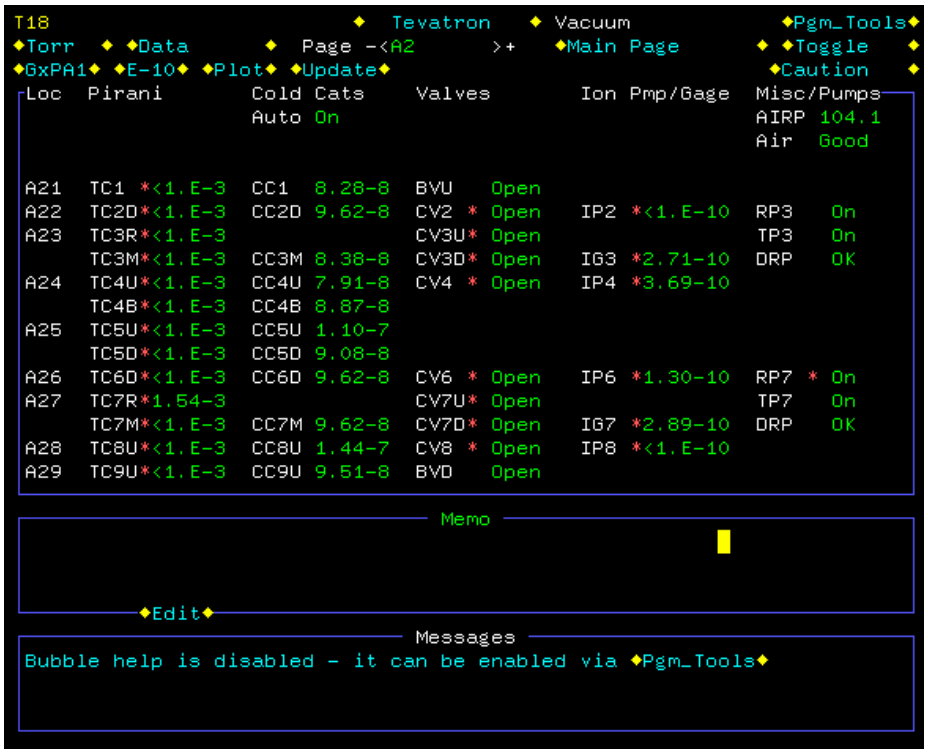
Vacuum

The Tevatron vacuum system is divided into 3 types: cold beam tube; warm beam tube; and cryostat insulating vacuum. Each type is discussed below.

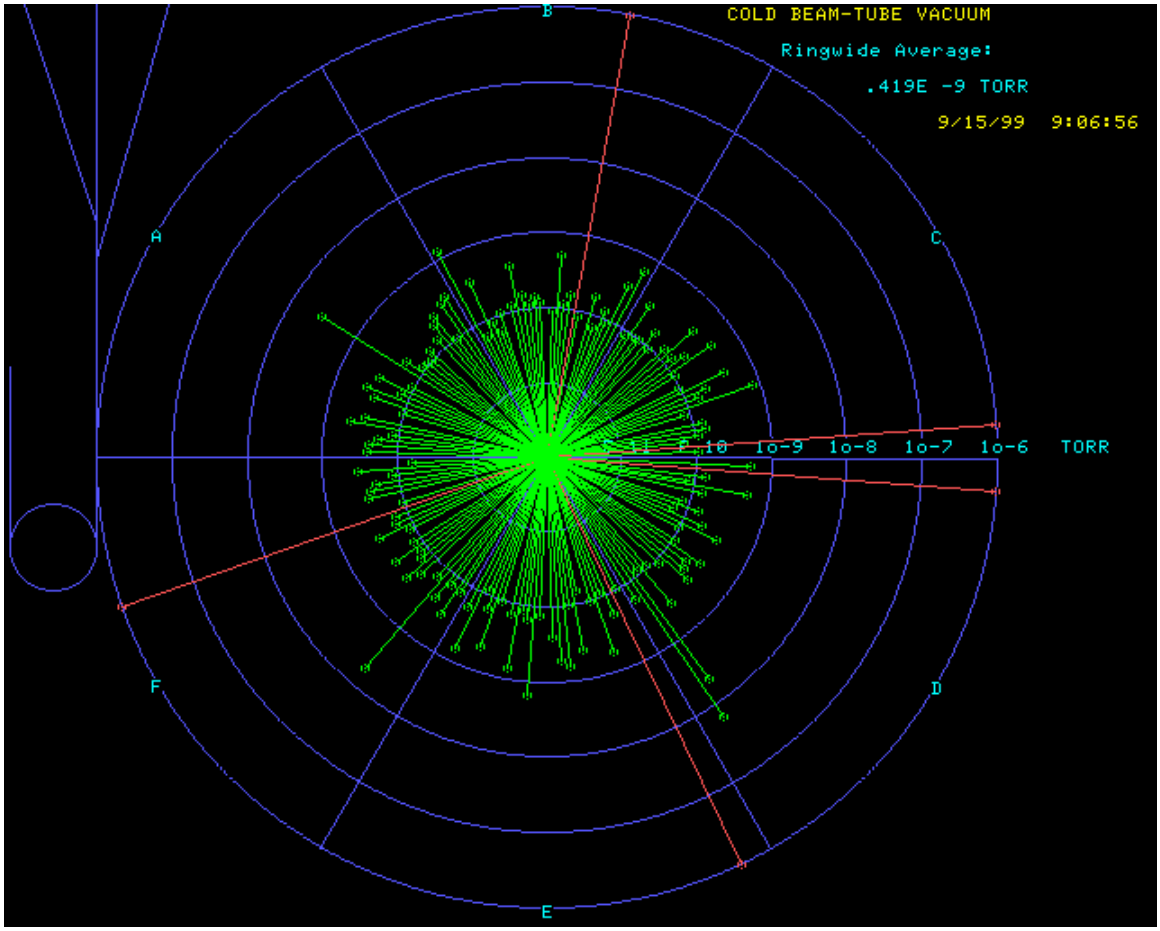
1) Cold Beam Tube Vacuum

The beam tube vacuum is completely separate from the cryostat vacuum. Beam tube vacuum is divided into 24 sections coinciding with the 24 cryogenics loops. These can each be isolated by remotely controlled beam valves at the turnaround box between each section. The beam tube is cold (4.6 K) at all but the 6 long straight sections and each of the "17" and "48" locations.

The beam tube is pumped down initially by portable pumps which are not a permanent part of the system. After pump down, the vacuum is maintained by 4 ion pumps per house (not including the zero houses since these are warm). These ion pumps are at the "X2", "X4", "X6", and "X8" locations, where X=1, 2, 3, 4, except the "4" house where the last ion pump is at the "49" location. There are also 2 nude ion gauges per house. The term nude refers to the ion gauge not having a glass bulb. These are at the "X3" and "X7" locations. The ion pumps have an ion current readback which is converted to pressure, although the ion gauges are more accurate. The typical working ranges of the ion pumps and ion gauges are 10^{-6} torr to 10^{-10} torr. In practice the beam tube, once cold, needs no external pumping anyway. The liquid helium temperature of the tube condenses out any gases, even helium. This is referred to as cryo pumping. The beam tube vacuum is required to be on the order of 10^{-8} torr, and is usually better.

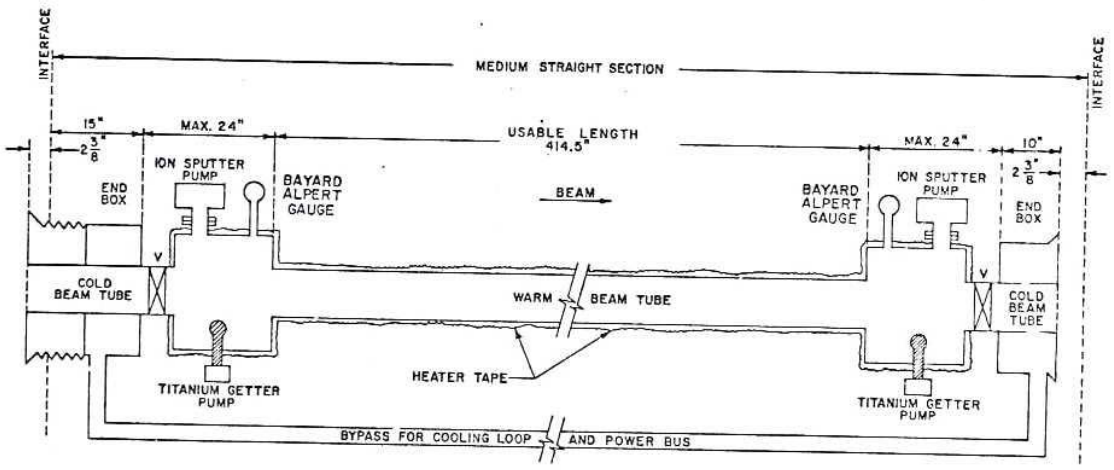


The beam valves at each end of a house are interlocked. They can only be opened when an ion pump permit exists at both houses on each side of the valve. The ion pump card is responsible for issuing an ion pump permit. An ion pump card has 6 inputs. Four of these are the 4 ion pumps per numbered house and the last two are the two ion gauges. Only the 4 ion pumps take part in the permit. A permit is issued by the card when at least 2 of the 4 ion pumps are on. Typically, the 24 numbered houses have only 1 ion pump card, while the zero houses can have up to 3 cards. Each of the 3 cards must issue a permit for that zero house to issue an ion pump permit. The ion pumps will trip off in 15 minutes if the vacuum exceeds 10^{-6} torr for that duration.



2) Warm Beam Tube Vacuum

The warm beam tube resides at room temperature and exists at the 6 long straight sections and each of the "17" and "48" locations. These sections generally contain specialty devices such as kickers, injection and extraction magnets, RF, etc. The vacuum equipment at these locations is an integral part of these devices and thus is different at each warm section. Each warm straight has an isolation valve at each end. Some of the long straights have intermediate valves to break up the section.



3) Cryostat Insulating Vacuum

The cryostat vacuum insulates the liquid nitrogen and liquid helium in the magnets. With a good vacuum, the main heat load becomes conduction through the magnet super-insulation and radiant heat across the vacuum. Radiant heat is a function of the temperature to the fourth power. This is why the liquid nitrogen shield exists; $77^4 << 273^4$. The cryostat vacuum is required to be only better than 10^{-5} torr. It is usually much better, about 10^{-7} torr. The cryostat vacuum is broken into half-cells by permanent barriers at each quadrupole. This is to facilitate the isolation and elimination of vacuum leaks. The half-cell vacuum sections are each connected by remotely controlled cryostat valves. Once the vacuum is good in 2 adjacent half-cells the valve is normally left open.

Each numbered house has 2 pumping stations. These are located at the "X3" and "X7" locations, X=1, 2, 3, 4. The pumping stations are all identical. A station consists of a small turbo-molecular pump (100 l/s) and a rotary roughing pump (5 l/s). The pumping stations are connected to both sides of the barrier at this location ("X3" or "X7") through two cryostat valves (upstream and downstream). The roughing pumps are remotely controlled while the turbos simply come on automatically when the rougher has pumped the manifold down.

Pressure measurements in the cryostat vacuum are made by two types of devices: thermocouples and cold cathodes. Thermocouples are also called Pirani gauges and

measure vacuum between atmospheric pressure and 10^{-3} torr. Cold cathodes measure from 10^{-3} to 10^{-8} torr. The cryostat valves are interlocked to the thermocouples. When there is a significant pressure differential between two half-cells or between the pumping manifold and either upstream or downstream half-cell, the appropriate cryostat valve will not open on command. It will hold a "request" to the valve and open when the differential pressure is low. The cold cathodes are interlocked to the thermocouples; the cold cathode will turn on when the adjacent thermocouple reads less than 1 micron (10^{-3} torr).

The vacuum system and the cryogenic system are invariably coupled. A magnet string can never be cooled down when the insulating vacuum is poor. On the other hand, if there are no leaks, a vacuum that is only fair will be cryopumped by cooling the magnet string.

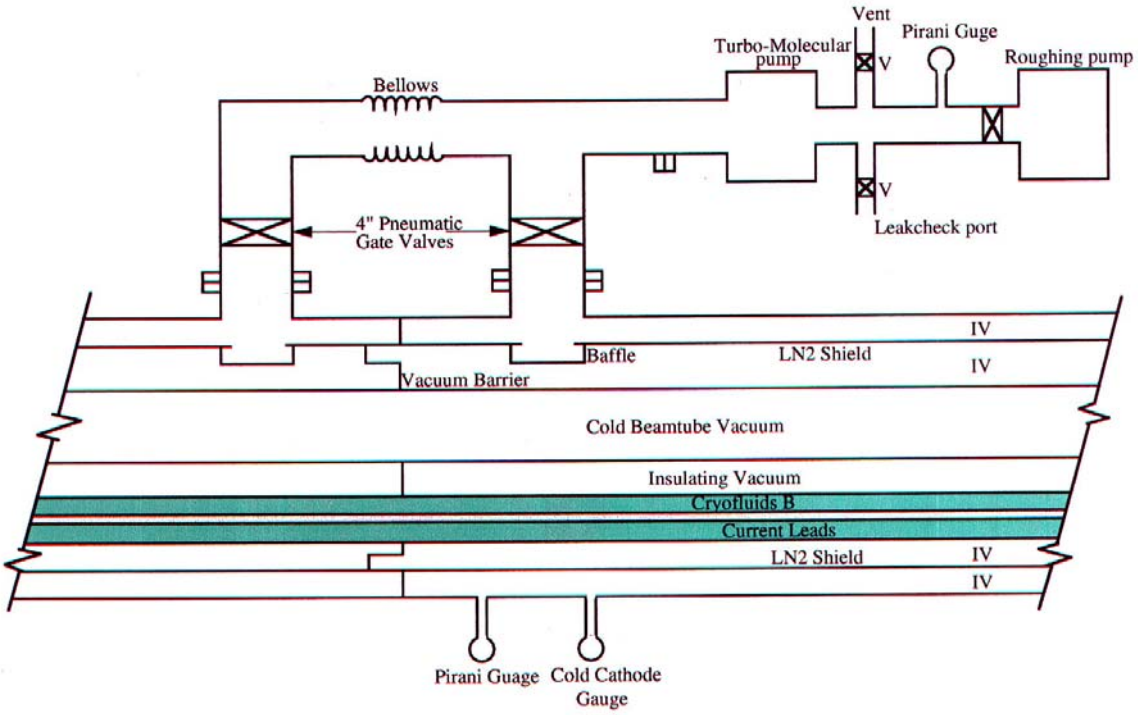


Fig. 5-4 Pump station for insulating vacuum.